

## PATENT ABSTRACTS OF JAPAN

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TANAKA SHINICHI**(54) METHOD FOR IMPROVING FATIGUE CHARACTERISTICS OF TITANIUM ALLOY COMPONENT, AND TITANIUM ALLOY COMPONENT THEREWITH****(57)Abstract:**

**PROBLEM TO BE SOLVED:** To provide a method for improving deterioration of fatigue strength caused by a roughened surface of the plasma-carburized titanium alloy component, and a titanium alloy therewith.

**SOLUTION:** This method for improving fatigue characteristics is characterized by shot peening the surface of the titanium alloy component, which has been solutionized, aged, and plasma carburized in an atmospheric gas having a temperature of 350-950° C and a pressure of 10-2,000 Pa, through projecting hard steel particles with sizes of 20-200 µm, which are accelerated into projection speeds of 50-200 m/s by a compressed air having an adjusted pressure. Thereby, the fatigue strength is improved due to delay of cracking generation, because an incubation time before the cracking generation caused by the roughened surface in a carburizing process is prolonged, as a result of increase in strength of the surface layer, remaining of compressive stress, and smoothing of the surface on the above component.

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**CLAIMS**

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[Claim(s)]

[Claim 1] The fatigue property improvement approach of titanium-alloy components of performing shot-peening processing which makes a hard particle colliding with the front face of the titanium-alloy components which performed plasma carburization processing at a necessary projection rate.

[Claim 2] The fatigue property improvement approach of a titanium-alloy component according to claim 1 of having performed solution treatment before said plasma carburization processing.

[Claim 3] The fatigue property improvement approach of a titanium-alloy component according to claim 1 of having performed solution treatment and aging treatment before said plasma carburization processing.

[Claim 4] The fatigue property improvement approach of a titanium-alloy component according to claim 1 of having performed annealing processing before said plasma carburization processing.

[Claim 5] The fatigue property improvement approach of titanium-alloy components given in either of claims 1-4 which have the temperature of the controlled atmosphere of said plasma carburization processing in the range of 350 to 950 degrees C, and are in the range the pressure of whose is 10-2000Pa.

[Claim 6] The fatigue property improvement approach of titanium-alloy components given in either of claims 1-5 to which the particle size has said hard particle in the range of 20 to 200 micrometers.

[Claim 7] The fatigue property improvement approach of titanium-alloy components given in either of claims 1-6 which have the projection rate of said hard particle in the range of 50 - 200 m/s.

[Claim 8] The titanium-alloy components formed in either of claims 1-7 using the fatigue property improvement approach of a publication.

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DETAILED DESCRIPTION

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[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to the fatigue property improvement approach of titanium-alloy components, and, specifically, relates to the titanium-alloy components using the improvement approach of the fatigue strength of titanium-alloy components and it which performed plasma carburization processing.

[0002]

[Description of the Prior Art] Since the titanium alloy has the property excellent in specific strength, fracture toughness, thermal resistance, corrosion resistance, etc., the location important as an aircraft material is occupied, the amount used is also increasing, it comes to be used for primary-structure members, such as a shell plate, a frame, fittings, and fasteners, with improvement in the speed, enlargement, etc. of the aircraft, and the titanium alloy with reinforcement higher than pure titanium is mainly used. Moreover, a real example is seen [ in / the ocean field, the generation-of-electrical-energy field, the automobile field, etc. / in a titanium alloy / taking advantage of the balance of the good corrosion resistance and specific strength ].

[0003] For example, with fasteners, such as a bolt and a nut, since it is used on the severe conditions which receive repeated stress including thermal stress in many cases, properties, such as good sliding nature for securing the required bolting force on the necessary abrasion resistance as a threaded fastener and a design, are required. However, in the state of non-lubrication, coefficient of friction of a titanium alloy is large, and when using it for said threaded fastener, slide member, etc., the problem of seizure produces it. Although coefficient of friction can generally be lowered by using lubricant, such as a lubricating oil, a graphite, and molybdenum disulfide, in order to be the seizure prevention which cannot bear a prolonged activity but is durable, it is required to carry out hardening processing on the surface of a titanium alloy.

[0004] As the aforementioned surface hardening, the method of performing plasma carburization processing is learned. The up heat insulator of the processing interior of a room [ processing / this / plasma carburization ] in a vacuum ambient atmosphere is connected to the anode plate of DC power supply. The installation base of a processed material is connected to the cathode of said DC power supply, apply direct current voltage among two poles, and glow discharge is produced. From the manifold formed in the key point of a processing room, first, mixed gas with inert gas, such as hydrogen gas, an argon, or nitrogen, is introduced, and it is made to collide with the front face of a metal processed material, and cleans by an oxide skin etc. carrying out affix clearance of hydrogen, or the ionized argon or nitrogen. Subsequently, the mixed gas of the gas for carburization of hydrocarbon systems, such as methane and a propane, and the gas for dilution is introduced. Generate activated carbon ion by said glow discharge, and this activated carbon ion collides and adheres to the front face of metal processed materials, such as a titanium metal, and are spread inside. Or when the accelerated activated carbon ion collides with the front face of a metalizing object, it is the processing which is driven into the interior, combines with metal atoms, such as Ti, and forms the hardening layer of metallic carbide, such as TiC, in the surface section directly.

[0005]

[Problem(s) to be Solved by the Invention] However, in said plasma carburization down stream processing, for colliding also with a front face, in case nitrogen and hydrogen which the activated carbon ion accelerated at the time of carburization processing collided on the surface of the titanium alloy, and ionized in the cleaning treatment of pretreatment eliminate affixes, such as an oxide skin, off etc., the surface roughness of a titanium alloy becomes large compared with plasma carburization processing before, and produces surface deterioration. Since a gap of crystal grain is brought about and the part serves as a source of concentration of stress, the irregularity of such surface deterioration, i.e., a front face, becomes the cause of becoming easy to generate a crack and reducing the fatigue strength of a titanium alloy sensitive to the notch effects, such as a crack, especially.

[0006] Moreover, since the hydrogen which is the presentation of the gas for carburization is also ionized and it exists in an ambient atmosphere, compared with the case where said carburization processing is not performed, hydrogen becomes easy to invade into the profit in a processed material at the surface section. Therefore, said carburization processing object flare-out-comes to be easy of the so-called hydrogen embrittlement, such as carrying out fatigue breaking by the load lower than lowering and tensile strength of toughness.

[0007] The aircraft components with which, as for these things, safety is demanded also in a service condition severe as mentioned above serve as a fault fatal for the titanium-alloy components used in other industrial fields, such as the ocean field and the generation-of-electrical-energy field, of course.

[0008] Then, the technical problem of this invention is providing the surface deterioration of titanium-alloy components which performed plasma carburization processing with the titanium-alloy components processed by the method of improving lowering of fatigue strength, and this approach.

[0009]

[Means for Solving the Problem] In order to solve the aforementioned technical problem, in this invention, it was made to perform shot-peening processing which makes a hard particle collide with the front face of the titanium-alloy components which performed plasma carburization processing at a necessary projection rate.

[0010] If it does in this way, by a collision and impact of said hard particle, a countless crater is formed in the front face of titanium-alloy components, the reinforcement will rise [ the hammered-out surface layer ] plastic deformation with a lifting and work hardening exceeding the yield point, and compressive stress will remain to said surface layer. And a front face is graduated by making grain size of a hard particle small rather than the surface roughness of the titanium-alloy components after plasma carburization processing.

[0011] The latent period to the crack initiation on the basis of the hydride which deposited in the interface of surface irregularity and alpha phase of the surface section, and a parent phase becomes long, and crack initiation is delayed [ ease / by smoothing of a front face / this compressive residual stress acting like hydrostatic pressure, and making small the tension stress component at the time of an external force operation, and / lifting of the reinforcement of this surface layer, and / stress concentration ]. By these, lowering of the fatigue strength by aforementioned surface deterioration and aforementioned hydrogen embrittlement can be improved, and the plasma carburization processing article which has necessary fatigue strength can be realized. [0012] Solution treatment can be performed before said plasma carburization processing.

[0013] Thus, before plasma carburization processing, if solution treatment is performed and aging treatment is performed after plasma carburization processing, the hardening layer of TiC can be given to the surface section, and reinforcement can be raised.

[0014] Solution treatment and aging treatment can also be performed before said plasma carburization processing.

[0015] Thus, before performing plasma carburization processing, also by performing solution treatment and aging treatment, the hardening layer of TiC can be given to the surface section, and reinforcement can be raised.

[0016] Annealing processing can be performed before said plasma carburization processing.

[0017] When reinforcement to the extent that solution treatment and aging treatment are performed is not required, annealing processing can be carried out before plasma carburization processing, and the hardening layer of TiC can be given to the surface section, and an organization can be stabilized.

[0018] It is desirable that the temperature of the controlled atmosphere containing the gas for carburization of said plasma carburization processing is in the range of 350 to 950 degrees C, and it is in the range the pressure of whose is 10–2000Pa.

[0019] In the pyrosphere by which the controlled atmosphere temperature of plasma carburization processing exceeds 950 degrees C, the organization after solution treatment makes it big and rough, and there is fear of construction material degradation, like the reinforcement of said titanium alloy falls. Moreover, diffusion inside [ of said activated carbon ion with which said controlled atmosphere temperature collided with the front face of the titanium–alloy components of a processed material in the low temperature range lower than 350 degrees C ] components becomes difficult, and it becomes difficult for soot to generate on the front face of said component, and to form a desired carburization layer, i.e., the hardening layer of TiC, in the surface section.

[0020] In the high voltage with which the pressure of a controlled atmosphere exceeds 2000Pa, even if the activated carbon ion concentration in a controlled atmosphere will become high, the trespass carbon content of the surface section of titanium–alloy components will be in a saturation state and activated carbon ion collides with said product front face more than this, it is not spread inside but soot comes to generate to a bill-of-materials side.

[0021] It becomes impossible moreover, for the concentration of the amount of activated carbon ion in a controlled atmosphere to become [ the pressure of a controlled atmosphere ] low with the low voltage of less than 10Pa, and for the trespass carbon content of the surface section of titanium–alloy components to decrease too much, and to form the hardening layer of desired TiC, but to improve the aforementioned abrasion resistance and sliding nature enough.

[0022] It is desirable for the particle size to have said hard particle in the range of 20 to 200 micrometers.

[0023] By ceramic particles', such as metal particles', such as steel casting's, and high-speed steel's, cast iron's, JIKONIUMU's, silicon carbide's, and an alumina's, being hard, and making them collide with the front face rather than titanium–alloy components generally, a surface layer pushes, it extends, the yield point is exceeded, plastic deformation is produced, and lowering of fatigue strength is prevented by lifting of a surface layer on the strength, the residual of compressive stress, and smoothing of a front face as mentioned above. In addition, particle-izing is easy for each of these metals and ceramics.

[0024] If the projection energy of each particle will become small too much if said particle size becomes smaller than 20 micrometers, and particle size becomes larger than 200 micrometers insufficiently to push, extend and carry out plastic deformation of the surface layer of titanium–alloy components by collision, the projection energy of each particle becomes large too much, and a surface indentation becomes large, and surface roughness will increase and it will become disadvantageous in respect of fatigue resistance.

[0025] Furthermore, if the hard particle of the above-mentioned size range is used, since [ of components ] the maximum of compressive residual stress appears in a front face mostly, it is advantageous in respect of fatigue resistance.

[0026] It is desirable for the projection rate of said hard particle to be in the range of 50 – 200 m/s.

[0027] If it becomes inadequate for the projection energy of the hard particle accelerated carrying out plastic deformation of the surface layer of a titanium alloy if said projection rate becomes smaller than 50 m/s and a projection rate becomes large rather than 200 m/s Even when the hard particle which the projection energy of the hard particle accelerated becomes large too much, and a surface indentation becomes large, and is in the aforementioned size range is used, in order to form many deep indentations, it becomes less desirable also for fatigue resistance.

[0028] In addition, since the projection rate of a hard particle is difficult for many factors concerning it to display numerically for every shot-peening processing when based on an air operated accelerator, beforehand, with an optical measuring method etc., it matches the compression fluid at the time of the projection rate of a hard particle, and projection, i.e., the gage pressure of said compressed air, and can manage it with said gage pressure.

[0029]

[Embodiment of the Invention] Below, the shot-peening art of the titanium-alloy components of the operation gestalt of this invention is explained with reference to attached drawing 1 R> 1.

[0030] The shot-peening art of this invention is applicable to both a mold (alpha+beta) titanium alloy a beta titanium alloy and a semi- alpha titanium alloy.

[0031] For example, if it describes about Ti-6aluminum-4V which are the typical alpha plus beta titanium alloy which was excellent in the balance of reinforcement and toughness and was excellent in heat treatability and a moldability, said solution treatment will be performed by carrying out water cooling, after holding about 70 minutes from 20 minutes in the range of 900 to 970 degrees C, and said aging treatment will be performed by holding to a 480 to 690 degrees C temperature requirement for 2 to 8 hours.

[0032] It is surrounded with the heat insulator attached in the inner skin of the furnace shell of a heating furnace, a processing room is formed, and the equipment (JEOL industrial company make) used for said plasma carburization processing is heated with the heating element with which this processing room consists of a graphite rod prepared in that interior. The up heat insulator of the processing interior of a room is connected to the anode plate of DC power supply, and the installation base of a processed material is connected to the cathode of said DC power supply, apply direct current voltage among two poles, produce glow discharge, ionize the gas for carburization introduced from the manifold formed in the key point of a processing room, generate activated carbon ion, this activated carbon ion is made to collide on the surface of a processed material, and carburization processing is performed. Moreover, the vacuum pump is connected to the processing room in order to make the interior into a vacua.

[0033] Washing processing of the titanium alloy of a processed material is first carried out using an organic solvent or a supersonic wave. And the titanium alloy of the processed material placed on the installation base of said processing room is heated with said heating element in less than 950-degree C 350-degree-C or more temperature region equivalent to carburization processing temperature, it introduces into the processing interior of a room, and the gas for cleaning which consists of inert gas which mixed the hydrogen gas plasma-ized by said glow discharge performs cleaning treatment which is over off about the oxide film on the front face of a titanium alloy.

[0034] In addition, as this cleaning approach, the nitrogen gas containing nitrogen fluoride (NF3) gas is introduced into the processing interior of a room in the above-mentioned temperature region, and there is also a method of permuting said oxide skin by the fluoride film.

[0035] Subsequently, flow regulation is carried out, respectively, mixed gas with the hydrogen gas which has a cleaning action as the liquefied petroleum gas and dilution gas as gas for carburization in said processing interior of a room is introduced so that the pressure of the processing interior of a room may become a vacuum ambient atmosphere within the limits which are 10Pa - 2000Pa, and the temperature of this mixed gas, i.e., a controlled atmosphere, is held with said heating element in the range which is 350 degrees C - 950 degrees C so that a titanium alloy can maintain carburization processing temperature. And the carbon in a liquefied petroleum gas is ionized by said glow discharge, activated carbon ion is generated, this activated carbon ion collides on the surface of a titanium alloy, is spread, and combines with Ti, and a carburization layer, i.e., the hardening layer of TiC, is formed in that surface section.

[0036] The carburization nature gas of the processing interior of a room is exhausted after termination of said carburization processing, nitrogen gas is introduced into the processing interior of a room, it is cooled to ordinary temperature and titanium-alloy components are taken out from a processing room.

[0037] Said titanium-alloy component is set to the peening room of an air operated peening machine. And with an accelerator The hard particle of the steel system of the range of 20 to 200 micrometers accelerated by the compressed air by which pressure regulation was carried out, or

a ceramic system so that the predetermined projection rate of the range of 50 – 200 m/s may be obtained Until it becomes the full coverage with which all processing sides, i.e., the front face of titanium–alloy components, are covered by the marks of a hard particle from the diameter of 5mm by a 9mm nozzle to 45 degrees – 90 degrees angle of projection Or projection is continued until it becomes a desired coverage (ratio of total of the marks area of the shot to the processing area A (B/A)). This projection time amount is in the range for about 10 – 180 seconds.

[0038] In addition, since the amount of projection and projection consistency of said hard particle influence the efficiency of shot peening and do not influence the reinforcement after shot peening, they can be decided by a configuration, magnitude, the target processing time, etc. of a processed material. Moreover, the glass particle which carried out melting balling-up of the glass can also be used as said hard particle, and compression fluids, such as compression nitrogen and a compression argon, can be used instead of being said compressed air.

[0039]

[Example 1] Solution treatment (they are after 1-hour maintenance and water cooling to 950 degrees C), and aging treatment (after 8-hour maintenance at 540 degrees C) the fatigue test specimen (notch parallel part die-length  $L_1 = 7.6\text{mm}$ ) shown in drawing 2 from the round bar with a diameter of 20mm by which air cooling was carried out of titanium–alloy Ti–6aluminum–4V Radius  $R_1 = 1.5\text{mm}$  of the shoulder of the notch parallel part diameter D of 1 = 6.6mm, and a notch parallel part, Parallel part die-length  $L_2 = 38\text{mm}$ , the parallel part diameter D of 2 = 10.5mm, radius  $R_2 = 0.8\text{mm}$  of the shoulder of a parallel part, Overall-length  $L_3 = 152\text{mm}$  is started. With the emery paper of No. 1000 After polish, After cleaning ultrasonically in an acetone, it heated even to temperature equivalent to carburization processing temperature in the processing interior of a room of the aforementioned plasma carburization processor, and the above-mentioned cleaning treatment was performed using the nitrogen gas which mixed hydrogen gas.

[0040] And the controlled atmosphere which consists of mixed gas with the hydrogen gas (flow rate 0.1 L/min) as the liquefied petroleum gas (flow rate 0.02 L/min) and the gas for dilution as gas for carburization was introduced into said processing room, 530 degrees C and this gas pressure performed about 30Pa, and the processing time performed plasma carburization processing on the conditions for about 40 minutes, the temperature, i.e., the carburization processing temperature, of this controlled atmosphere. After carburization processing termination, the controlled atmosphere was exhausted promptly, nitrogen gas was introduced into the processing room, and forced cooling of said each test piece of a processed material was carried out to ordinary temperature.

[0041] Then, said fatigue test specimen was set to the peening room of an air operated peening machine, the steel-casting particle whose mean particle diameter is about 50 micrometers was accelerated by the compressed air by which pressure regulation was carried out so that a projection rate might be set to s in about 100m /, from the projection nozzle with a diameter of 7mm, it projected between about 90 sec(s) and shot-peening processing was performed so that the front face of said test piece may be in the aforementioned full coverage condition.

[0042] The tension fatigue test was carried out using said fatigue test specimen which carried out such processing. this fatigue test — electromagnetism — based on the fatigue strength required of a real part article, stress conditions were set up using the resonance mold fatigue tester (Shimadzu make), and it carried out with maximum stress 530MPa, minimum stress 53MPa, a stress ratio 0.1, about 240 alternating stress MPa(s), and the frequency of 20Hz. the test result was shown in a table 1 — as — the case of STA processing + plasma carburization processing (processing number 2) — number of cycles about  $4.9 \times 10^5$  Target number of cycles 106 like [ in STA processing + plasma carburization + shot-peening processing (processing number 3) ] the case (processing number 1) of only STA processing although fractured \*\*\*\* — it did not result in fracture.

[0043]

[A table 1]

処理番号	処 理 内 容	繰返し数	破断の有無
1	S T A 処理	10 <sup>6</sup>	破断せず
2	S T A 処理 + プラズマ浸炭	4.9 × 10 <sup>5</sup>	破 断
3	S T A 処理 + プラズマ浸炭 + ショットピーニング	10 <sup>6</sup>	破断せず

[0044]

[Example 2] From the round bar with a diameter of 20mm by which annealing processing (they are after 2-hour maintenance and air cooling to 740 degrees C) was carried out of titanium-alloy Ti-6aluminum-4V the same fatigue test specimen as the case of an example 1 (notch parallel part die-length L — 1 = 7.6mm) shown in drawing 1 Radius R1 =1.5mm of the shoulder of the notch parallel part diameter D of 1 = 6.6mm, and a notch parallel part, Parallel part die-length L2 =38mm, the parallel part diameter D of 2 = 10.5mm, radius R2 =0.8mm of the shoulder of a parallel part, After starting overall-length L3=152mm and cleaning ultrasonically in an acetone after polish with the emery paper of No. 1000, it heated even to temperature equivalent to carburization processing temperature in said processing interior of a room, and the above-mentioned cleaning treatment was performed using the nitrogen gas which mixed hydrogen gas.

[0045] And the liquefied petroleum gas as gas for carburization (flow rate 0.02 L/min) (the controlled atmosphere which consists of mixed gas with the hydrogen gas (flow rate 0.1 L/min) as dilution gas was introduced into said processing room, in this controlled atmosphere temperature, i.e., carburization temperature, 760 degrees C and this gas pressure performed about 30Pa on the conditions of about 2 hours, and the processing time performed plasma carburization processing.) After carburization processing termination, carburization gas was exhausted promptly, nitrogen gas was introduced into the processing room, and forced cooling of said test piece of a processed material was carried out to ordinary temperature.

[0046]



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**DESCRIPTION OF DRAWINGS**

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[Brief Description of the Drawings]

[Drawing 1] The front view of the fatigue test specimen used for assessment of the fatigue strength in the fatigue property improvement approach of an operation gestalt.

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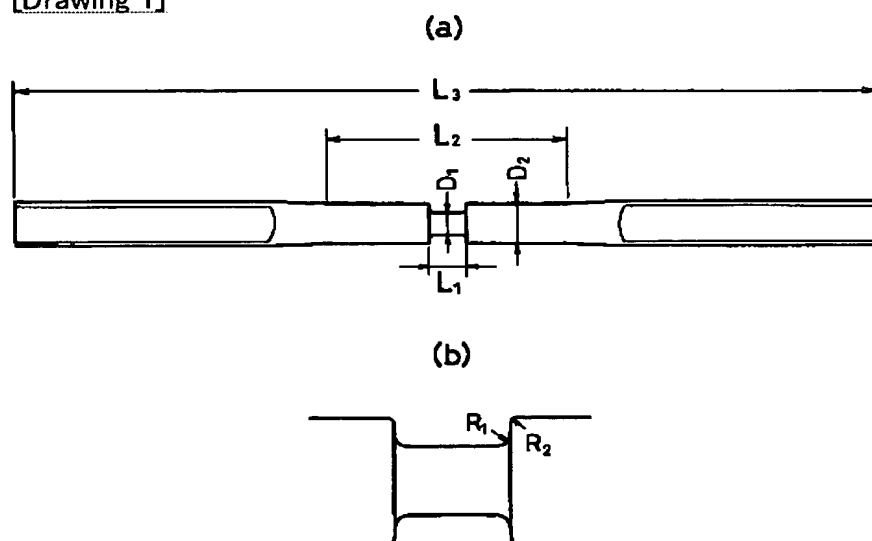
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**DRAWINGS**

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**[Drawing 1]**

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